
By WILSON B. EMERY.

INTRODUCTION.

The townships here described lie in the eastern part of the Osage Nation. (See fig. 1.) They include the towns of Avant and Skiatook, on the Midland Valley Railroad, which follows the valley of Bird Creek, a stream with rather broad alluvial bottoms that are devoted to farming. Much of the area consists of wooded ridges traversed by poor roads and little cultivated.

Field work in these townships was done between October, 1917, and February, 1918, by R. H. Wood, O. B. Hopkins, D. E. Winchester, C. S. Ross, P. V. Roundy, and the writer. The area mapped by each geologist is shown in the diagram inserted on Plate II. This diagram shows also the areas surveyed by different methods. Mapping by barometer and compass traverse is less accurate than plane-table work but when carefully checked, as in the present case, affords in the main a true representation of the actual structural conditions.

STRATIGRAPHY.

EXPOSED ROCKS.

The rocks exposed at the surface in this area belong to the middle Pennsylvanian. They comprise a series of sandstones, shales, and limestones, aggregating about 550 feet in thickness, and their character and succession are shown graphically in figure 2. Shale constitutes by far the larger portion of the exposed rocks, though there is considerable sandstone. Except for the Avant limestone, which is the most prominent and readily distinguishable bed in the region, limestone forms a very minor part of the exposed section.

No complete description of the stratigraphy will be given in this paper, but for the convenience of those who wish to do detailed geologic work in this region a few of the most prominent beds or key rocks will be described below.

Avant limestone.—The Avant limestone crops out through Tps. 22 and 23 N., R. 12 E. (See Pl. II.) At the quarry along the railroad between Avant and Oil City the Avant consists of 39 feet of fossiliferous massive gray limestone, overlain by 6 feet of thin platy limestone composed largely of fragments of crinoid stems and Bryozoa. The platy limestone maintains its thickness and character

N. $\frac{1}{2}$ sec. 18, T. 23 N., R. 12 E., and is well developed in the western part of this township and the eastern and northern parts of T. 23 N., R. 11 E. It is 2 to 5 feet thick and is dark gray on fresh fracture, but weathers into light-gray slabs. Weathered faces are dotted with innumerable *Fusulina* shells which resemble wheat grains. It lies from 95 to 100 feet above the top of the Avant limestone in the northern part of T. 23 N., Rs. 11 and 12 E., but in the southern part of these townships it is about 117 feet above the Avant. The *Fusulina*-bearing limestone was noted only here and there in T. 22 N., R. 12 E.

Shelly and red limestones.—About 20 feet below the *Fusulina*-bearing limestone in the region of Avant is a shelly limestone (see columnar section, fig. 2) which is a helpful stratigraphic indicator. In the southern part of T. 23 N., R. 12 E., this lower limestone grades into and is replaced by a heavy sandstone which forms the first topographic bench above the Avant limestone. From 20 to 30 feet above the *Fusulina*-bearing limestone is another thin limestone (the red limestone of the columnar section) which generally weathers vermilion and which also is a good marker.

Clem Creek sandstone.—The beds here designated Clem Creek sandstone embrace a series of massive medium-grained sandstones and thin lenticular shales aggregating 60 to 65 feet in thickness and are exposed along Clem Creek in the northwestern part of T. 23 N., R. 11 E. This formation is limited below by the red limestone already mentioned, and its upper limit is the top of a massive bed of sandstone 18 feet thick, which is marked by a line of woods at the base of a grass-covered prairie, developed on the overlying shale. This upper sandstone may be conveniently seen along the road in sec. 5, T. 23 N., R. 11 E., north of Clem Creek. Locally near the base of the overlying shale is another thin limestone that weathers red and is a very definite horizon marker. The top of the Clem Creek sandstone was mapped across T. 23 N., R. 11 E., as is shown on Plate II. It lies about 195 feet above the top of the Avant limestone.

Bigheart sandstone.—The name Bigheart sandstone was used by Snider¹ for a series of 175 feet of sandstone and shale exposed at and near the town of Bigheart, in T. 24 N., R. 11 E. The name Bigheart sandstone is here restricted to the basal massive sandstone of this series. In the area covered by this report 40 feet of this sandstone is present, and a typical exposure may be seen near the center of sec. 6, T. 23 N., R. 11 E. It forms a very distinct bench and is notably coarse, the lowest beds being conglomeratic. In places the conglomeratic beds are highly calcareous and weather rusty brown. Because of its slight induration the Bigheart readily crumbles into soft sand. The beds between the Bigheart and the top of the Clem

¹ Snider, L. C., Preliminary report on the clays and clay industry of Oklahoma: Oklahoma Geol. Survey Bull. 7, p. 221, 1911.

Creek sandstone consist principally of shale with minor quantities of thin sandstone. Directly underlying the Bigheart in T. 23 N., R. 11 E., is a gray shale from 20 to 35 feet thick. Locally the upper 6 feet of this shale is red. The base of the Bigheart lies from 345 to 360 feet above the top of the Avant limestone in this area.

ROCKS NOT EXPOSED.

A study of well logs shows that between the surface beds and the productive oil and gas zone in this area lie sandstone, shale, and limestone, and that the shale aggregates many times the thickness of the limestone and sandstone. This is clearly seen in Plate III, on which are shown graphically the rocks reported in the logs of wells drilled at several places in this area.

The first easily recognizable bed below the Avant limestone reached by the drill is a limestone 50 to 75 feet thick, usually called the Big lime by the drillers. It lies about 810 feet below the top of the Avant in sec. 6, T. 23 N., R. 12 E., and 870 feet below in sec. 29, T. 23 N., R. 11 E. The intervening rocks consist almost entirely of shale. Below the Big lime is 125 to 160 feet of shale, followed by a limestone 50 to 65 feet thick. This is named the "Oswego lime" by the oil men and lies 1,015 to 1,050 feet below the Avant. It is underlain by 300 feet or more of shale, containing one or more thin limestone beds, beneath which are a series of sands which contain the productive oil and gas zones of the district.

The top of the productive sandy series lies from 1,350 to 1,450 feet below the top of the Avant limestone. Gas is commonly encountered in the upper 50 to 125 feet of the series, and in places the gas sand is separated from the underlying oil-bearing sands by 25 to 100 feet of shale, but in other places there is no shale between the gas and oil-bearing parts of the series. The oil-bearing sand aggregates 120 to 150 feet in thickness in this region.

Any sand productive of oil in this zone is commonly referred to as the Bartlesville sand, but it may or may not be the same as the productive sand at Bartlesville. The fact, however, that the Bartlesville sand near Bartlesville lies about 1,350 feet below the top of the Avant limestone lends color to the supposition that the sands in the two localities occupy similar stratigraphic positions. About 150 feet below the top of the Bartlesville is in places a thinner oil-bearing sand known as the Burgess sand, and other thin sands are present locally. The entire series of sands, including the gas sand, are probably best regarded as associated parts of the Bartlesville sand, which in this region embraces the basal portion of the Cherokee shale—that is, of the Pennsylvanian.

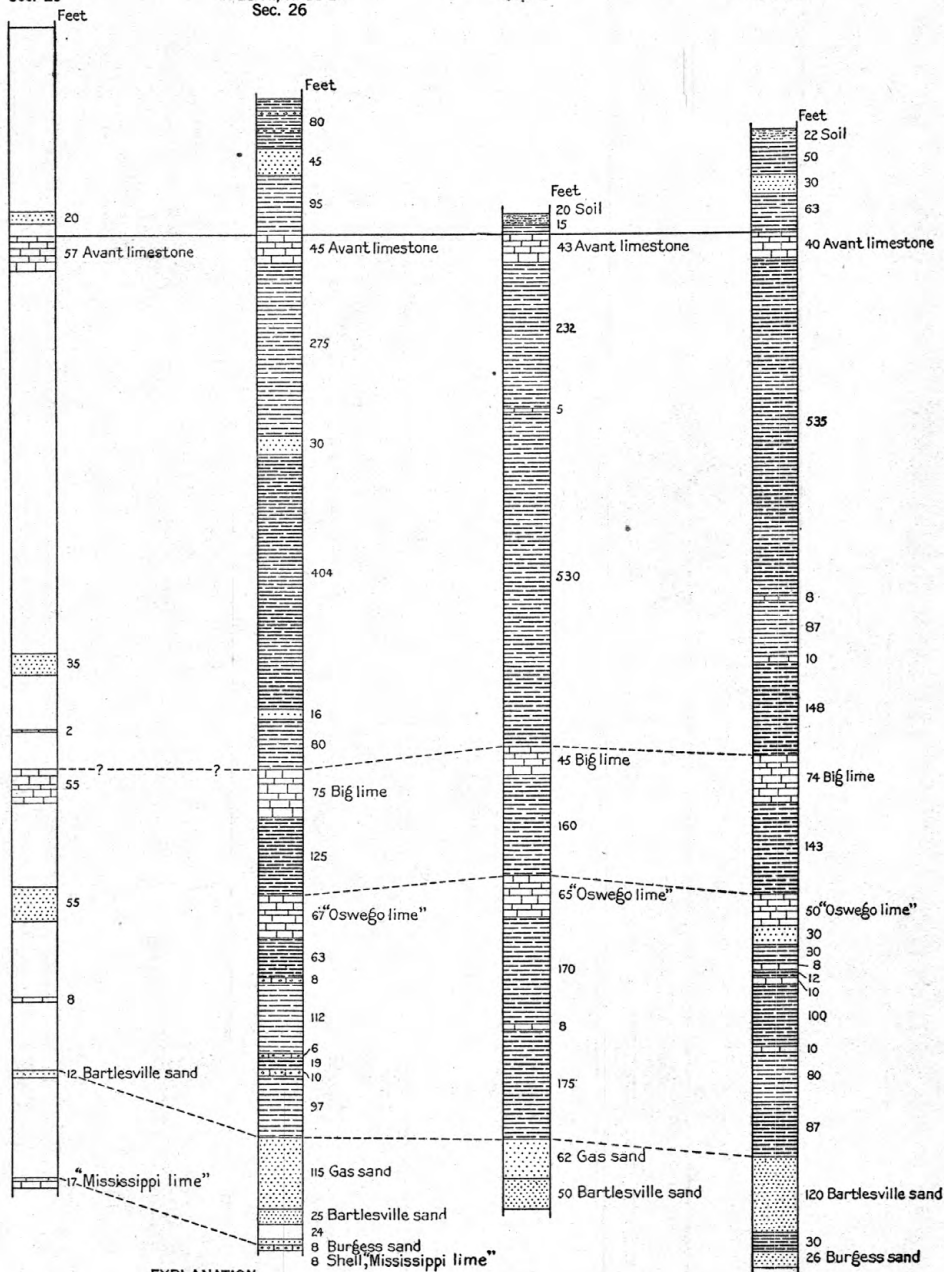
A few wells in this area have reached, beneath the Bartlesville and associated sands, a limestone generally known as the "Mississippi

Barnsdall Oil Co.
Well No. 11
T. 23 N., R. 11 E.
Sec. 29

Finance Oil Co. and
Livingston Oil Co.
Well No. 11
T. 23 N., R. 11 E.
Sec. 26

Laurel Oil & Gas Co.
Well No. 43
T. 23 N., R. 12 E.
Sec. 6

Finance Oil Co.
Well No. 6
T. 23 N., R. 12 E.
Sec. 30



SELECTED WELL RECORDS IN T. 23 N., RS. 11 AND 12 E.

lime." The thickness of this limestone is not known, for it has not been completely penetrated. It may represent the Boone limestone of northeastern Oklahoma and southeastern Kansas, but without more detailed information than is now at hand such a correlation can not be definitely asserted. At several localities in eastern Osage County beds below the top of this limestone have yielded oil in commercial amounts, and no well should be regarded as constituting a complete test of a district unless it penetrates the "Mississippi lime" to a depth of 300 feet.

STRUCTURAL FEATURES.

AREAS OF FAVORABLE STRUCTURE.

This area is a portion of a much larger region in which the general dip is northwesterly. The presence of an easterly dip is therefore significant, for it indicates an upfold which may yield commercial quantities of oil. The rocks in T. 22 N., R. 12 E., dip gently northwest with few irregularities, in conformity with the regional structure. Beyond, in T. 23 N., R. 12 E., and the southeastern part of T. 23 N., R. 11 E., is a broad zone of large open folds, and to the northwest, in the northwestern part of T. 23 N., R. 11 E., is a zone of closer folding. There are few faults in these townships. The structure is shown on the map (Pl. II). The contours are based solely on surface data and are drawn on a theoretical bed 500 feet below the top of the Avant limestone.

The largest upfold is the Avant anticline, south of the town of Avant, which affects the attitude of the rocks over a number of square miles in the southwestern part of T. 23 N., R. 12 E., and the southeastern part of T. 23 N., R. 11 E. The crest of the anticline in the SW. $\frac{1}{4}$ sec. 30, T. 23 N., R. 12 E., is outlined by the 340-foot contour. The lowest closed contour is the 280-foot, giving a closure of more than 60 feet, effective over a roughly circular area of about 4 square miles. Beyond this area anticlinal noses radiate irregularly, as for example in secs. 31 and 20, T. 23 N., R. 12 E. There is also a broad plunging fold in sec. 19, T. 23 N., R. 12 E., and similar folds occur in secs. 23, 24, and 36, T. 23 N., R. 11 E. In the NW. $\frac{1}{4}$ sec. 35, T. 23 N., R. 11 E., and the SW. $\frac{1}{4}$ sec. 31, T. 23 N., R. 12 E., are the crowns of two subsidiary domes on the flanks of the major fold. Although both these domes are low on the flank of the large anticline, they offer promise as prospective oil territory, especially the dome in sec. 35, T. 23 N., R. 11 E., which has a very steep dip on the west, toward the bottom of a large syncline. In sec. 18, T. 23 N., R. 12 E., the dip is so low as to make the structure therein effect that of a terrace.

The Avant anticline is cut on the south by a fault which trends southeast and crosses the south line of sec. 30, T. 23 N., R. 12 E., about a quarter of a mile west of the southeast corner of the section.

(See Pl. II.) As the maximum throw of this fault is but 15 feet, it probably has had no important effect on oil accumulation.

A synclinal axis trends northeast from the southeast corner of sec. 31 to and beyond the southwest corner of sec. 21 and limits the anticline on the southeast. At the nearest point the axis of this syncline is a little more than a mile from the crest of the Avant anticline. On the west the rocks dip west for more than 2 miles from the anticlinal crest to the bottom of a synclinal depression which extends north through secs. 34, 27, 22, and 15, T. 23 N., R. 11 E. A synclinal axis extending southeast from sec. 2, T. 23 N., R. 11 E., to sec. 17, T. 23 N., R. 12 E., in a general way following the alluvial valley of Bird Creek, limits the Avant anticline on the north and northeast. The axis of this syncline is 2 to 3 miles from the crest of the Avant fold.

The Avant fold has already been considerably drilled, and the presence of petroleum in it has been thoroughly demonstrated. A consideration of the structure indicates that the productive area may be extended somewhat to the south and southeast in secs. 29, 30, 31, and 32, T. 23 N., R. 12 E., and to the west and southwest in secs. 26, 35, and 36, T. 23 N., R. 11 E. Locations which the writer believes favorable for test wells are indicated on Plate II in secs. 23, 34, and 35, T. 23 N., R. 11 E., and sec. 31, T. 23 N., R. 12 E. The productive sand which such holes will seek is of course the Bartlesville, but if these holes are to be complete tests they should be drilled at least 300 feet below the top of the "Mississippi lime," which is totally untested in the Avant anticline. Beds below the top of the "Mississippi lime" have been found productive of oil in certain other parts of Osage County, and if oil is encountered in commercial quantity in them in these tests an extensive oil reserve beneath the Avant anticline may confidently be expected.

A second prominent upfold in the area is the Candy Creek anticline, in the northeastern part of the fractional T. 23 N., R. 12 E., east of the town of Avant. The axis of this anticline extends north near the west line of sec. 15 into sec. 10, where it turns sharply to the east. The 330-foot contour closes east of the edge of the mapped area and, owing to the sharp change in strike, this contour outlines a boot-shaped area, which is about half a square mile in extent. This anticline has two crowns, one in the NW. $\frac{1}{4}$ sec. 15 and the other in the SW. $\frac{1}{4}$ sec. 10. Both crowns are outlined by the 340-foot contour. In sec. 3 a small fault with a throw of less than 10 feet cuts the beds in a direction a little west of north but has probably had no effect on oil accumulation. In the western part of sec. 9 there is a small subsidiary anticline. The 290-foot contour is the lowest closed contour around this secondary fold, which is separated from the main fold by a small shallow syncline. The main anticline is limited on the west by a rather broad syncline, the axis of which in a general

way follows the alluvial valley of Bird Creek. A sharp northward-trending syncline near the county line in sec. 15 limits the anticline on the southeast.

The value of the Candy Creek anticline as oil territory has been demonstrated. Consideration of the structure leads to the conclusion that the beds on this fold may be expected to be productive from the east border of Osage County westward down the dip as far as the beds now producing in the two west tiers of sections in the township.

In the S. $\frac{1}{2}$ sec. 7, T. 23 N., R. 11 E., is the crown of the Hardy dome, which has a closure of more than 40 feet and includes a delta-shaped inclosed area of about $1\frac{1}{2}$ square miles, though the rocks are upfolded over a considerably larger area. A small secondary dome occurs on the flank of the major dome in the E. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 8, T. 23 N., R. 11 E. The major dome is limited on the east, north, and south by synclines whose axes lie about a mile from the crest, but to the west the synclinal axis lies more than $1\frac{1}{2}$ miles distant. Recent drilling on the crown of the Hardy dome has resulted in the bringing in of gas wells of considerable size. The flanks of the dome have not yet been tested, but there is every reason to expect that oil in commercial quantities will be encountered. The west flank appears especially favorable, and it is possible that oil will be obtained for some distance down this flank in T. 23 N., R. 10 E.

Southeast of the Hardy dome is a narrow anticline, the Lombard anticline, the axis of which extends north and northeast from the NW. $\frac{1}{4}$ sec. 28 through the central part of sec. 21 into the SE. $\frac{1}{4}$ sec. 16, T. 23 N., R. 11 E. The 170-foot contour is the lowest closing contour around this anticline, and as the crest of the fold is outlined by the 200-foot contour, there is a closure of over 30 feet. The inclosed area, which is cucumber-shaped, amounts to about 1 square mile. The anticline has two crowns, one in the NE. $\frac{1}{4}$ sec. 21 and the other just south of the center of the section, separated by a saddle over 10 feet deep. On the southwest this anticline merges with a northwestward-dipping monocline, and on the north it plunges into a faulted syncline. The regular northwest dip of the west flank is interrupted by an attenuated anticlinal nose extending northwest from the southeast corner of sec. 20 to and beyond the northwest corner of the section. On each side of this nose a syncline extends east and southeast toward the main uplift. The anticline is limited on the southeast by a rather broad syncline which trends northeast. The axis of this syncline is in places less than half a mile from the crest of the anticline. In the writer's opinion the Lombard dome has excellent possibilities as prospective oil territory. Test wells in the SE. $\frac{1}{4}$ sec. 16 or the SW. $\frac{1}{4}$ sec. 21, in places shown on the map or at any point between these places, will be favorably located structurally. If oil is found the productive beds may reasonably be ex-

pected to extend far down the anticlinal nose that trends northwestward through sec. 20.

Just south of the north quarter corner of sec. 33, T. 23 N., R. 11 E., is the crown of the Brown anticline, which has a closure of more than 30 feet and an inclosed area of about $1\frac{1}{2}$ square miles in secs. 28, 32, and 33. The axis of this anticline trends northeast. On the northwest the beds dip in that direction for more than 2 miles to the bottom of the limiting syncline, but on the east the axis of the complementary syncline is less than a mile distant. This syncline plunges both north and south from a low divide in the major syncline, at the north line of sec. 34, and its southern part is a closed depression more than 30 feet deep. The structure of the Brown fold is very favorable for oil accumulation, and oil in commercial quantity has already been found there.

In sec. 31, T. 23 N., R. 11 E., is the small but well-defined Fox dome, which is a part of a large fold that embraces also the Brown anticline, just described. This dome is separated from the Brown anticline by a shallow saddle, whose axis is less than a mile to the east. The Fox dome is proved oil territory, having yielded oil from sands above the "Mississippi lime." The lower sands also warrant testing.

A broad, low dome, here called the Labardie dome, is present in secs. 3 and 4, T. 23 N., R. 11 E. This fold is cut in sec. 4 by a northwestward-trending fault having a maximum throw of about 20 feet, with the upthrown block on the west side of the fault trace. The Labardie dome is separated by a shallow syncline from a smaller dome, the crown of which is in the extreme northwest corner of sec. 2 and the NE. $\frac{1}{4}$ sec. 3 of this township. Southeast of these domes is a closed syncline in secs. 2 and 11, and southwest of them another closed syncline in secs. 5 and 8. The major syncline in which both these closed depressions are situated is faulted south of these domes in sec. 9. Of the two faults the western is the larger, having a maximum throw of about 30 feet in the S. $\frac{1}{2}$ NW. $\frac{1}{4}$ sec. 9. The throw of the other fault is less than 10 feet. Between the two faults the rocks have been folded into a small incomplete anticline flanked on the south by a small closed depression. Structurally this dome does not appear to be particularly favorable as prospective oil territory. A dry hole has already been drilled near its crest.

In the NW. $\frac{1}{4}$ sec. 4, T. 22 N., R. 12 E., occur two very small domes. These domes are in effect a single structural feature on a larger fold—an anticlinal nose. The writer believes as favorable a site as any other for a test hole is in the NW. $\frac{1}{4}$ sec. 4, as shown on the map, but a consideration of the structure leads to the conclusion that oil, if encountered, will probably not be found in large amount.

In secs. 9 and 10, T. 22 N., R. 12 E., the general westerly dip of the beds is interrupted by a local flattening that gives rise to a

terrace. This is a small structural feature and does not hold much promise as oil territory. The dry hole in sec. 9 was drilled in a structurally favorable location, but as its record is not available it is not known whether or not the hole actually reached all the sands and was an adequate test. Oil has been found in secs. 5 and 8 of this township under less favorable structural conditions, and if the hole already drilled was not a thorough test, further prospecting of this terrace is warranted.

AREAS OF UNFAVORABLE STRUCTURE.

In view of the spotted distribution of the producing wells in this region, it would be hazardous to state that certain structural features in this area are not favorable for oil. It seems extremely unlikely, however, that commercial quantities of oil will be found in the major synclines, such as that in secs. 2, 9, 8, 5, and 6 and that in sec. 19, T. 23 N., R. 11 E. A few small wells were found in sec. 5, but these are now abandoned. It also seems very improbable that oil in economic quantity will be obtained in the deep closed syncline in the southeastern part of sec. 33 and the southwestern part of sec. 34 of the same township. Another unfavorable area is the syncline in sec. 6, T. 22 N., R. 12 E., and adjacent sections.

PRODUCTION.

A study of the records of initial production of wells in T. 23 N., R. 12 E., which is the most thoroughly drilled township in the area (see map, Pl. II) and which may be considered typical of the area, shows that about two-thirds of the wells came in, after being shot, with yields of 50 barrels or less, and that wells with an initial production of over 500 barrels were extremely rare. It is probably safe to make the general statement that in the area here described only small producers may be expected. On the other hand, production continues for a long time, as is evident from the fact that some of the leases in T. 23 N., R. 12 E., have been producing since 1906.

The area of greatest uplift in T. 23 N., R. 12 E., is productive throughout its extent, even the syncline which follows the valley of Bird Creek yielding oil in commercial amounts. The production along the major uplift is spotted and does not appear to follow any general rule. One noteworthy fact is that on the crest of the major Avant uplift only gas has been encountered. For this reason the writer is of the opinion that leases on the crests of broad folds in this region will yield considerable gas. All the anticlines in the area which have so far been tested have, with the exception of the Labardie anticline, yielded oil in commercial amounts.